

# Air Quality Monitoring

## Caroline and Rocky Mountain House Area

October 2005 and January, May and June 2006

Final Report

### ***Introduction***

Alberta Environment conducts mobile air quality surveys each year as part of its air quality monitoring program. These surveys are unannounced and use the department's mobile air monitoring laboratory (MAML). The MAML is equipped to measure a number of air pollutants including ammonia, carbon monoxide, hydrocarbons, oxides of nitrogen, ozone, particulate matter, reduced sulphur compounds and sulphur dioxide.

For the current study, air quality surveys were conducted in the area of Caroline and Rocky Mountain House, Alberta. Monitoring was performed in the vicinity of eleven gas plants and industrial areas selected in consultation with Alberta Environment's Central Region office. There were a total of four surveys, each consisting of three consecutive days. Surveys were conducted in October 2005 and January, May and June 2006. During this sample period over sixty hours of data was collected.

The objectives for monitoring in the Caroline and Rocky Mountain House area were two fold: (1) identify and determine the concentrations of air pollutants near industrial facilities in the survey area, and (2) support on going work of the regional compliance and approval staff. To achieve these objectives, monitoring was carried out for at *least* one hour at each monitoring location. In almost all cases there were several hours of monitoring conducted at each site. This facilitated comparison to Alberta's Ambient Air Quality Air Quality Objectives (AAAQOs). AAAQOs are established to define desired environmental quality that will protect public health and ecosystems. These objectives are used by Alberta Environment to ensure good air quality through out the province.



ISBN No. 978-0-7785-6289-4 (Printed Edition)  
ISBN No. 978-0-7785-6290-0 (On-Line Edition)  
**March 28, 2007**

## Overview

**Total hydrocarbons (THC)** concentrations at six of the eleven stations were comparable to background levels (< 2 ppm). Hydrocarbon concentrations notably higher than 2 ppm were measured at *Newalta Stauffer* waste oil processing (Site 1), *Solex and Taylor Harmattan* gas plant (Site 3) and *Petrofund Ferrier* gas plant (Site 5). The maximum one-hour average total hydrocarbon concentration at these sites were 8.8, 6.8 and 8.5 ppm, respectively. A significant fraction of the THC at these three monitoring sites consisted of reactive hydrocarbons (RHC). Concentrations of Methane (CH<sub>4</sub>), the other constituent of THC, were approximately 2 ppm at all of the monitoring locations. Fugitive emissions are the most likely source of elevated hydrocarbons.

Elevated **total reduced sulphur (TRS)** was measured downwind of Husky Ram river sour gas plant (Site 10). The maximum one-hour average TRS concentration at this location was 0.015 ppm. Hydrogen sulphide (H<sub>2</sub>S) component of TRS was less than half at 0.006 ppm. This implies that at the time of measurement *other* reduced sulphur compounds formed a significant fraction of TRS. A maximum one-hour average H<sub>2</sub>S concentration of 0.008 ppm was measured downwind of Devon Ferrier Cardium #2. The air quality objective of 0.010 ppm was not exceeded at any of the monitoring locations.

Much like the TRS concentrations, elevated **sulphur dioxide (SO<sub>2</sub>)** concentrations were measured downwind of Husky Ram river sour gas plant (Site 10). The median and maximum one-hour concentrations of 0.011 ppm and 0.063 ppm, respectively, were significantly higher than concentrations measured at the other monitoring sites in this study. Elevated SO<sub>2</sub> and TRS concentrations downwind of this facility probably had contributions from emissions associated with sour gas processing. It should be noted however that the one-hour objective for SO<sub>2</sub> of 0.172 ppm was not exceeded.

Elevated **carbon monoxide (CO)** and **oxide of nitrogen (NO<sub>x</sub>)** were measured downwind of Sites 3, 9 and 11. Site 9 and 11 were located in Rocky Mountain House, and Site 3 was located downwind of Solex and Taylor Harmattan gas plant. Elevated concentrations at these locations were most probably due to motor vehicle exhaust. Elevated **polycyclic aromatic hydrocarbons** were also measured at Site 9 and 11, where light duty vehicles were thought to be the dominant source of emissions. The median one-hour average concentrations at these two sites were 22 and 25 ng/m<sup>3</sup>, respectively.

The highest median one-hour ***total suspended particle*** (TSP) was measured downwind of West Fraser LVL Mill and Keyera Strachan, combined. Elevated PM<sub>10</sub> and PM<sub>2.5</sub> were also noted at this location. Elevated concentrations may be due to the joint emissions from these two facilities. When monitored individually concentrations downwind of these facilities were notably lower.

## **Monitoring method and locations**

Air quality surveys in the area of Rocky Mountain House and Caroline, Alberta were performed using Alberta Environment's mobile monitoring laboratory (MAML). The MAML provides a "snapshot" in time and place of the quality of air. It is equipped to monitor ammonia, carbon monoxide, hydrocarbons, oxides of nitrogen, ozone, particulate matter, reduced sulphur compounds and sulphur dioxide simultaneously. A description of the MAML, as well as the detection limit of the various instruments on board are given in Appendix B.

A total of four surveys were conducted between October 2005 and June 2006. Each survey consisted of three consecutive days of monitoring. The monitoring schedule is presented in Table A4 in the appendix. In total, approximately 60 hours of data were collected downwind of eleven monitoring sites, which included industrial areas and gas plants. The locations of the monitoring stations are described in Table 1 and illustrated in Figure 1.

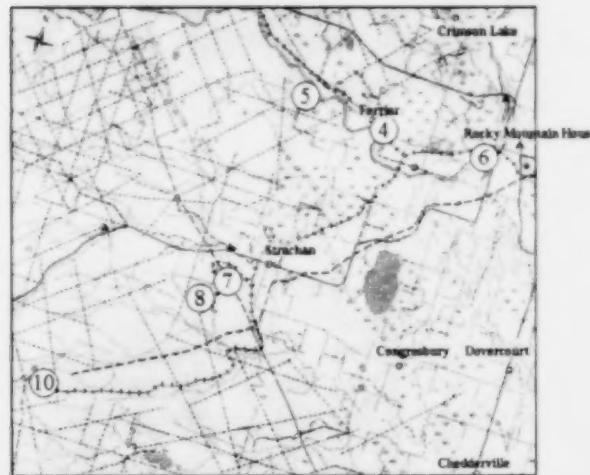
For each survey, an attempt was made to monitor downwind of all the sites described in Table 1. However, at times meteorological conditions (wind direction in particular) prevented monitoring downwind of some monitoring locations. That is to say, the MAML could not get access to a location close enough downwind of a facility. At each sample location, data was collected for at least one hour. One-hour average concentrations, calculated from these data were compared to one-hour Alberta Ambient Air Quality Objectives (AAAQO) in the result and discussion section.

**Table 1: Description of monitoring locations**

<b>Site</b>	<b>Facility</b>	<b>Industry type</b>
1	Newalta Stauffer	Oil Processing
2	Shell Caroline	Gas Plant
3	Solex and Taylor Harmattan	Gas Plant
4	Devon (nee Numac) Ferrier - Ferrier Acres	Gas Plant
5	Petrofund (nee Apache/NCE) Ferrier	Gas Plant
6	Devon (nee Numac) Ferrier Cardium #2	Gas Plant
7	West Fraser LVL Mill (nee Sunpine)	Saw Mill
8	Keyera (nee Keyspan) Strachan	Sour Gas Plant
9	The town of Rocky Mountain House, east side	Industrial Area
10	Husky Ram River	Sour Gas Plant
11	Spongberg Enterprises, North side of Rocky Mountain House	Oil Industry Service
7&8	Monitoring influenced by both West Fraser LVL Mill and Keyera Strachan	Mill and Sour Gas



A



B



C

Figure 1: Maps of MAML monitoring locations (circled numbers), descriptions of the indicated sites are given in Table 1.

## **Results and Discussion**

At most locations, monitoring was conducted for more than one hour. In discussing the results, the median one-hour average and the maximum one-hour average concentrations are presented. The median concentration is a common way of representing the central value for environmental data. Fifty percent of the one-hour averages at a location are below the median one-hour average concentration and fifty percent are above. Further justification for using the median concentration is presented in Appendix B.

Many areas in Alberta are pristine and certain pollutants that Alberta Environment monitors for are found in concentrations below the lower detection limit of the instruments onboard the MAML. A dataset may contain a large number of concentrations below the detection limit and a few concentrations within the operating range of the MAML instruments. In such cases, it is possible to have a median one-hour average concentration that is 'undetectable' or below the lower detection limit (*bd*) while still having a 'detectable' maximum one-hour average concentration. The median and maximum one-hour averages illustrate the mid as well as the highest one-hour concentrations measured at a location. These concentrations were compared to established **Alberta Ambient Air Quality Objectives** (AAAQO). In addition, median one-hour concentrations from other MAML surveys and permanent monitoring stations are presented for comparison. The key in Figure 2 illustrates how the median and maximum one-hour average concentrations are represented in the following section.

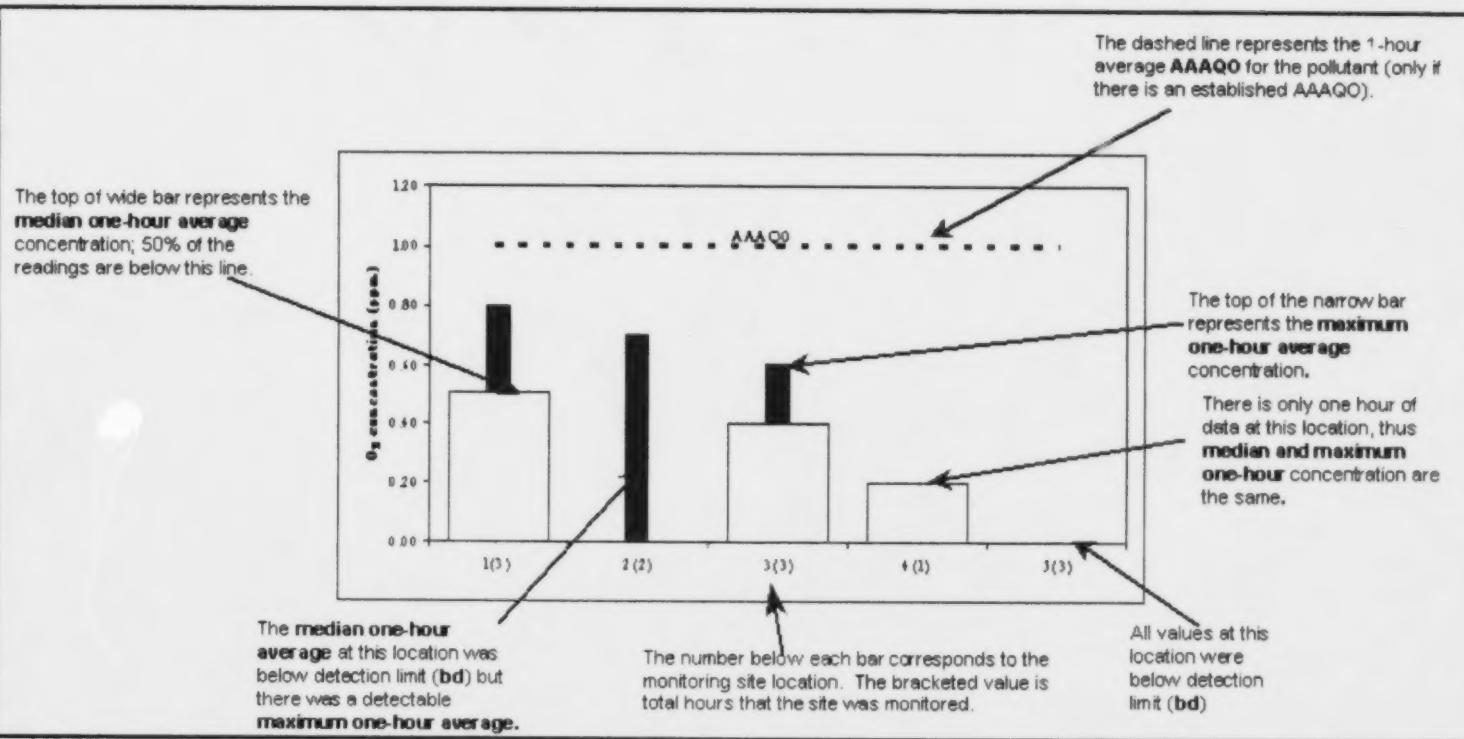


Figure 2: A key for interpreting the figures in the following section.

## Hydrocarbons

The term "total hydrocarbons" (THC) refers to a broad family of chemicals that contain carbon and hydrogen atoms. Methane ( $\text{CH}_4$ ), a non-reactive hydrocarbon, is the most common hydrocarbon in the earth's atmosphere. As a result, for most measurements around Alberta, concentrations of THC and  $\text{CH}_4$  are equivalent (Table A3) and a background concentration of about 2 ppm is typically measured. Reactive hydrocarbons (RHC) form the remaining fraction of THC. RHC are important because: (1) they can react with oxides of nitrogen in the presence of sunlight to form ozone; and (2) some RHC can be toxic (at high concentrations) to humans, animals or vegetation. The major sources of hydrocarbons include vegetation, vehicle emissions, gasoline marketing and storage tanks, petroleum and chemical industries and fugitive emissions such as leaks and evaporation of solvents.

For the current study, THC concentrations comparable to background levels (< 2 ppm) were measured at more than half the monitoring locations (at 6 of the 11 sites). Figure 3 illustrates that median one-hour average for THC at **Sites 2, 4, 7, 8, 10 and 11** were below 2 ppm. Elevated THC concentrations were measured downwind of oil and gas processing plants and industrial area of Rocky Mountain House (**Sites 1, 3, 5, 6 and 9**).

Median one-hour average  $\text{CH}_4$  concentrations at all of the monitoring locations were very close to or below 2 ppm (Figure 4). Thus, elevated THC were due to increases in RHC concentrations. Note that **Sites 1, 3, 5, 6 and 9**, where elevated THC were measured, were also the only locations where the median one-hour average concentrations for RHC were above detection limit (Figure 5).

Of the five locations where THC concentrations greater than 2 ppm were measured, notably higher THC and RHC concentrations were measured at **Sites 1, 3 and 5**. A maximum one-hour average THC of 8.8 ppm and a maximum one-hour average THC of 6.5 ppm, were measured at **Site 1** (Newalta Stauffer). The maximum concentrations at **Site 5** (Petrofund) were similarly elevated, with a maximum one-hour average of 8.5 ppm for THC and 5.4 ppm for RHC. At **Site 3** (Solex and Taylor Harmattan), the maximum one-hour average THC and RHC were 6.8 and 4.0 ppm, respectively. Elevated THC concentrations were most probably the result of fugitive emissions from facilities upwind of the monitoring locations. Elevated concentrations at **Site 3** may also have had contributions from nearby truck emissions (Table A4).

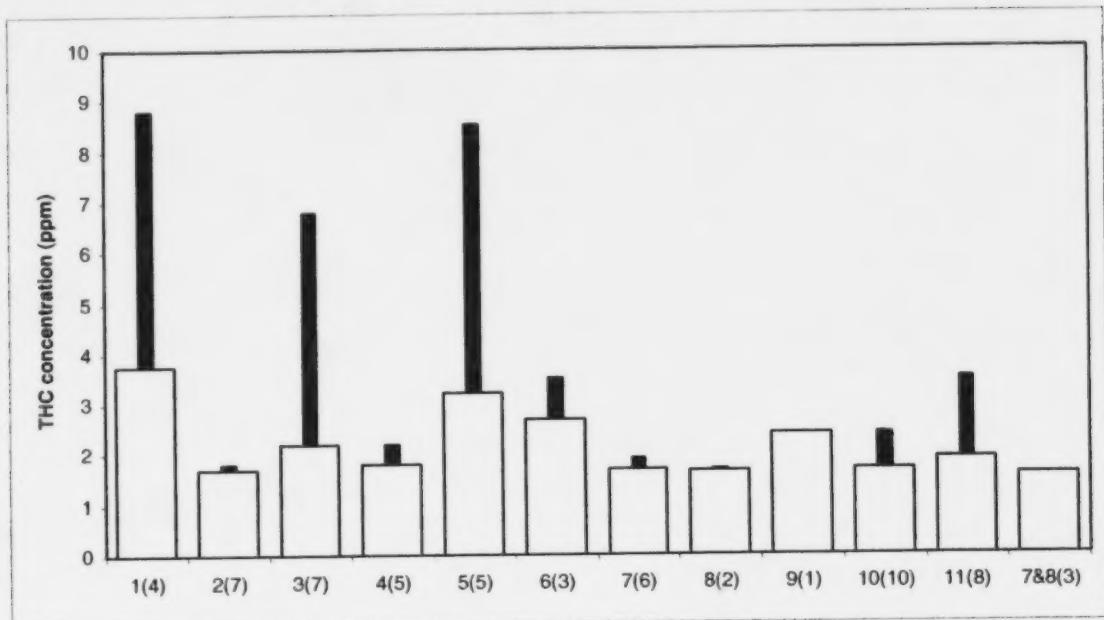


Figure 3: Median and maximum one-hour average concentrations for THC. The y-axis for Figures 3 to 5 are identical to facilitate comparison.

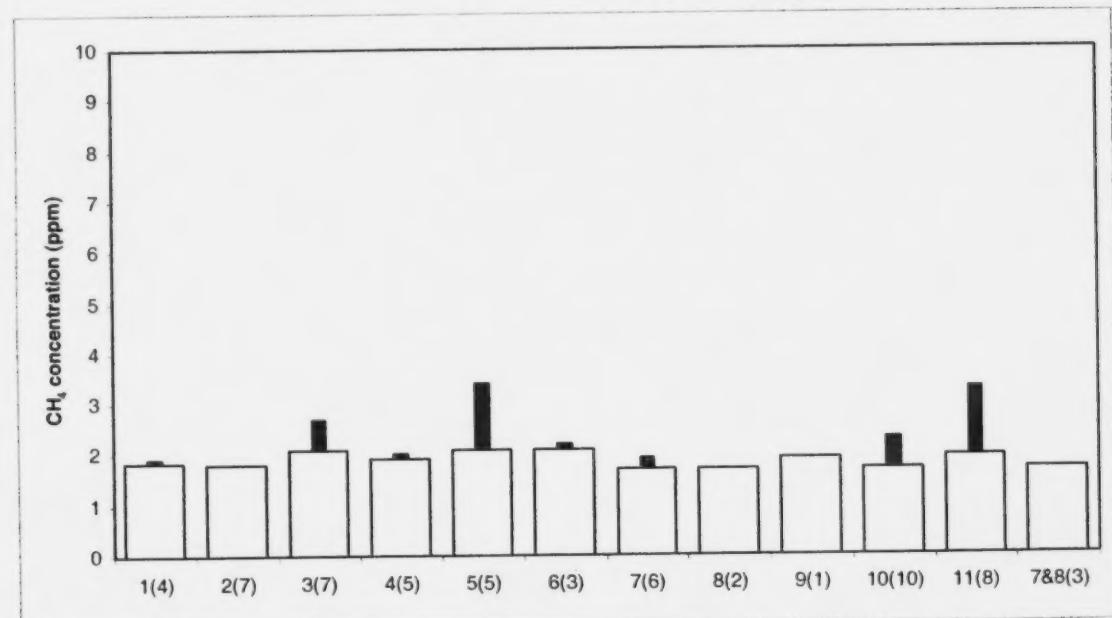
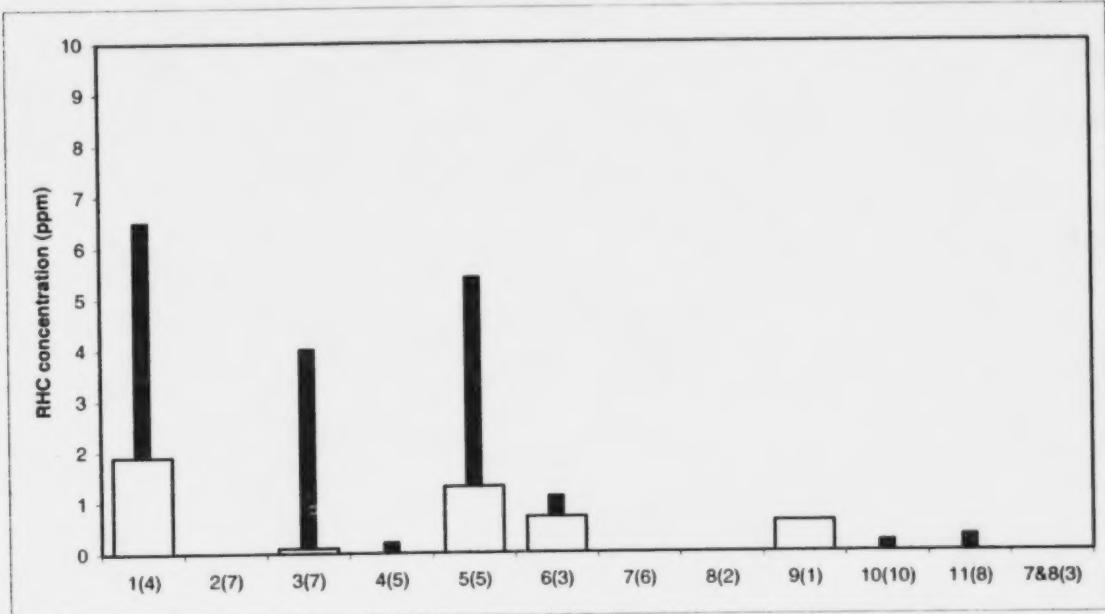


Figure 4: Median and maximum one-hour average concentrations for CH<sub>4</sub>.



**Figure 5: Median and maximum one-hour average concentrations for RHC.**

## **Total Reduced Sulphur (TRS) Including Hydrogen Sulphide (H<sub>2</sub>S)**

Total reduced sulphur includes hydrogen sulphide (H<sub>2</sub>S), mercaptans, dimethyl sulphide, dimethyl disulphide, and other sulphur compounds. Total reduced sulphur **does not** include sulphur dioxide, this pollutant will be discussed in a separate section. The major industrial sources of H<sub>2</sub>S and TRS are fugitive emissions from petroleum refineries, tank farms for unrefined petroleum products, natural gas plants, petrochemical plants, oil sands plants, sewage treatment facilities, pulp and paper plants that use the Kraft pulping process, and animal feedlots. Natural sources of H<sub>2</sub>S include sulphur hot springs, sloughs, swamps and lakes. Natural sources were not expected to be the major contributors for the current survey.

During other MAML surveys, H<sub>2</sub>S composes a large fraction of TRS concentrations, with typical concentrations of about 0.001 ppm. This is evident in Table A3, where TRS concentrations are equivalent to H<sub>2</sub>S concentrations for most MAML surveys. For some sites in the current study, TRS may have contained measurable concentrations of *other* reduced sulphur, excluding H<sub>2</sub>S. The median one-hour TRS concentrations ranged from below detection limit to 0.003 ppm (Figure 6). The median one-hour average H<sub>2</sub>S concentrations at many of the monitoring locations were below detection limit (Figure 7). However, there were measurable maximum one-hour concentrations indicating periodical increases in H<sub>2</sub>S concentrations. The maximum one-hour average concentrations ranged from 0.001 to 0.008 ppm. The highest one-hour average H<sub>2</sub>S concentration was measured at **Site 6** (Devon Ferrier, gas plant). However this concentration did not exceed the one-hour AAAQO for H<sub>2</sub>S of 0.010 ppm.

The highest TRS concentrations were measured at **Site 10** (Husky Ram River, sour gas plant). The median and maximum one-hour average of 0.003 and 0.015 ppm respectively were measured. The median and maximum one-hour average H<sub>2</sub>S concentrations at the same locations were 0.002 and 0.006 ppm, respectively. The results indicate that at **Site 10**, there were significant contributions from other reduced sulphur compounds (other than H<sub>2</sub>S) to TRS concentrations. Emission associated with sour gas processing is the most likely source of elevated TRS concentrations at **Site 10**.

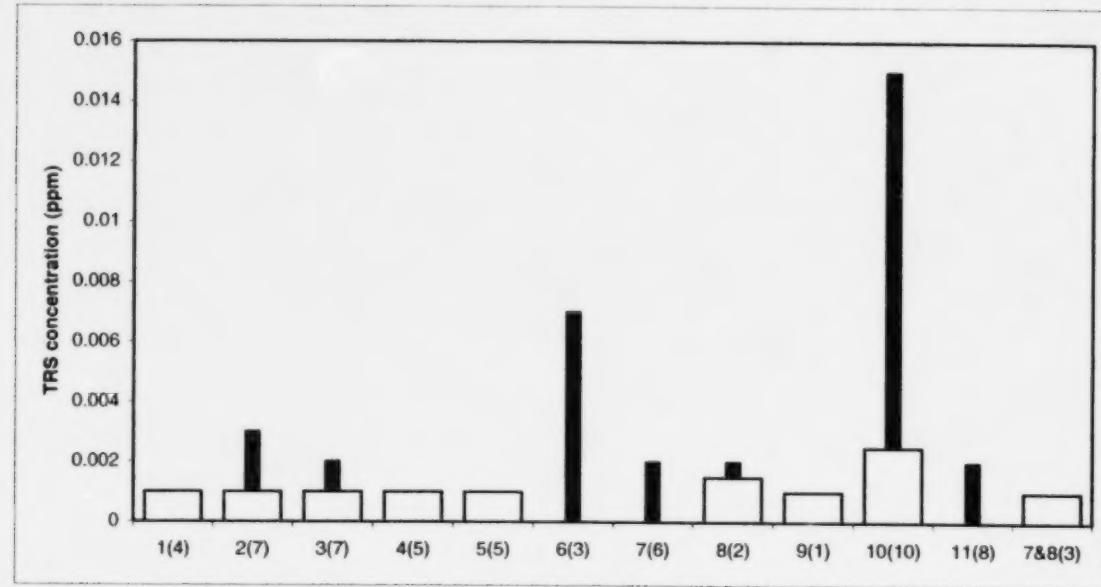


Figure 6: Median and maximum one-hour average concentrations for TRS.

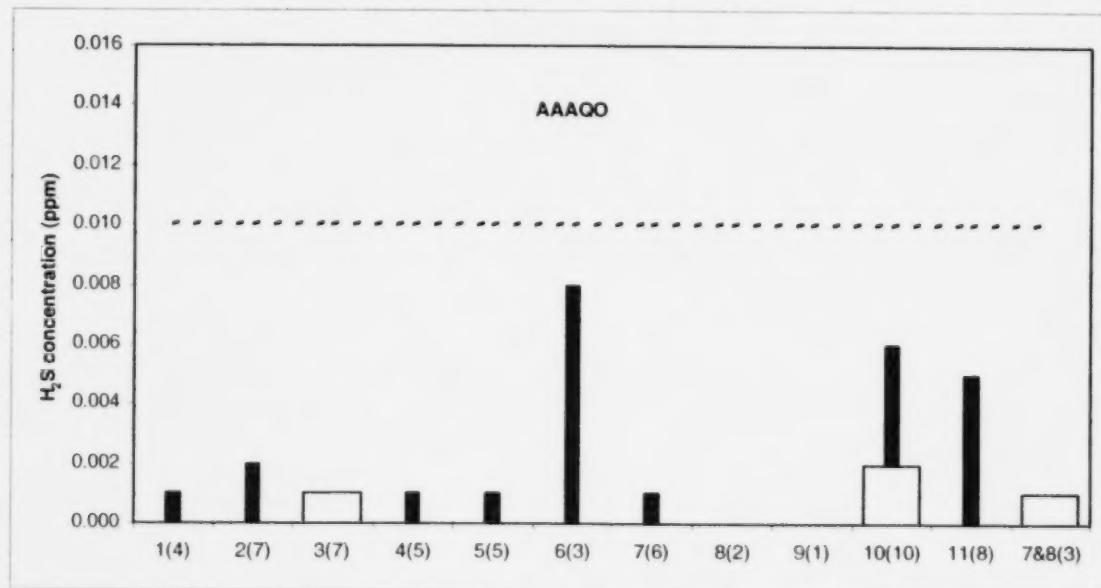


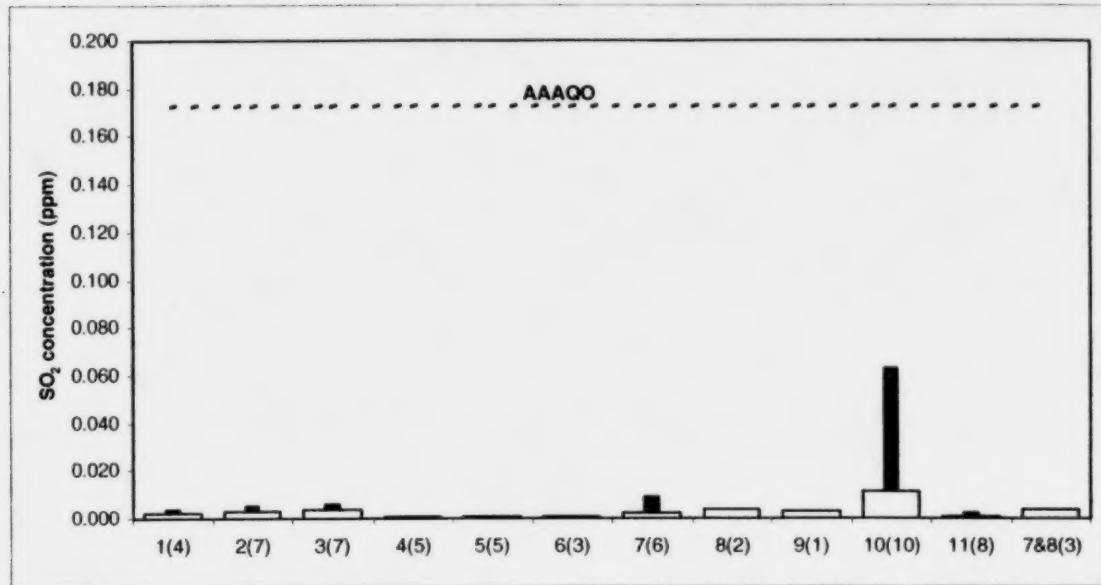
Figure 7: Median and maximum one-hour average concentrations for H<sub>2</sub>S.

## **Sulphur Dioxide ( $SO_2$ )**

In Alberta, natural gas processing plants are responsible for close to half of the  $SO_2$  emissions in the province. The oil sands facilities and power plants are also major  $SO_2$  sources. Other sources include gas plant flares, oil refineries, pulp and paper mills and fertilizer plants.

The highest  $SO_2$  concentration was measured at **Site 10** (Husky Ram River). The median one-hour average at this site was 0.011 ppm; the maximum one-hour average concentration was notably elevated at 0.063 ppm. However, these concentrations did not exceed the one-hour AAAQO of 0.172 ppm (Figure 8). At other monitoring locations, the median one-hour average  $SO_2$  concentrations were significantly lower, ranging from below detection limit to 0.004 ppm. Husky Ram River (**Site 10**) is one of two sour gas plants included in the study. Elevated  $SO_2$  readings downwind of this location were probably influenced by emissions associated with sour gas processing. Furthermore, total reduce sulphur (TRS) concentrations were also elevated at this site relative to the other monitoring locations (see section on TRS).

The median one-hour average concentrations at other MAML surveys ranged from below detection limit to 0.004 ppm (measured in Whitecourt during 2000/01 survey). Buffalo Viewpoint, Mannix and Mildred Lake are three permanent monitoring stations located in Fort McMurray (industrial). For 2006, the median one-hour  $SO_2$  concentration was below detection limit for Buffalo Viewpoint and Mildred Lake. The median one-hour concentration at Mannix was 0.001 ppm. Thus, concentrations measured during the current study, with the exception of **Site 10**, were comparable to those measured at other locations in Alberta.



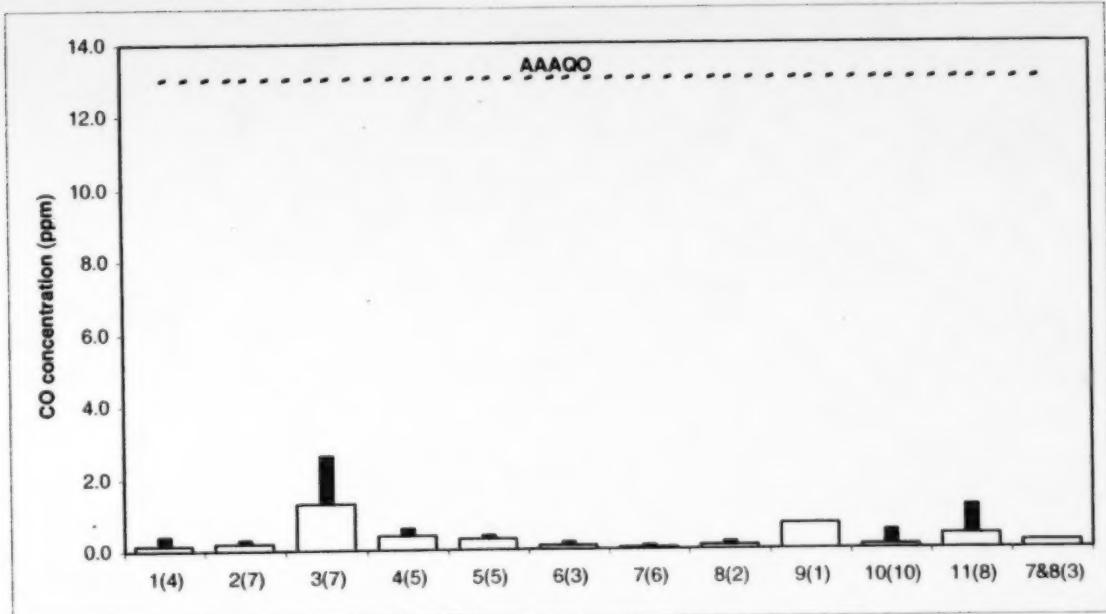
**Figure 8: Median and maximum one-hour average SO<sub>2</sub> concentrations.**

## **Carbon monoxide (CO)**

Carbon monoxide (CO) is emitted into the atmosphere primarily from incomplete combustion of fuels such as gasoline, oil and wood. Sources of CO include motor vehicle exhaust, fireplaces, industry, aircraft, natural gas combustion and forest fires.

Alberta has a one-hour CO objective of 13 ppm. One-hour average concentrations measured during the current study were well below the one-hour AAAQO (Figure 9). The highest CO concentrations were measured at Solex and Taylor Harmattan (**Site 3**). A median and maximum one-hour average concentrations of 1.3 and 2.6 ppm respectively were measured at **Site 3**. Elevated concentrations at this site were most probably due to motor vehicle emissions; continuous truck traffic was noted during some of the surveys at this location (Table A4). Motor vehicle emissions are also thought to be the source of the somewhat elevated concentrations at **Site 11** (Spongberg Enterprises, north side of Rocky Mountain House) and **Site 9** (Eastside of Rocky Mountain House). The median one-hour averages at **Site 11** and **9** were 0.4 ppm and 0.7 ppm, respectively. Both these sites were located near major roadways (Figure 1C).

In comparison, median one-hour CO for 2006 at Edmonton and Calgary Central were 0.3 and 0.4 ppm (Table A3). Motor vehicle emissions are the major source of CO at these two monitoring locations. CO concentrations at the urban locations are comparable to the median at **Site 11** but lower than those measured at **Site 9** and **3**. This being said, the urban CO concentrations presented are the median for the year. The one-hour median concentrations during other MAML surveys were for the most part approximately 0.2 ppm, however concentrations as high as 0.5 ppm have been measured at Banff (Table A3). Most MAML surveys are conducted away from motor vehicle traffic.



**Figure 9: Median and maximum one-hour average carbon monoxide concentrations.**

## **Oxides of Nitrogen (NO, NO<sub>2</sub> and NO<sub>x</sub>)**

The sum of nitrogen dioxide (NO<sub>2</sub>) and nitric oxide (NO) is known as oxides of nitrogen (NO<sub>x</sub>). During high temperature combustion as in the burning of natural gas, coal, oil and gasoline, atmospheric nitrogen may combine with molecular oxygen to form NO. In the atmosphere, NO will readily react with ozone (O<sub>3</sub>) to form NO<sub>2</sub>. NO<sub>2</sub> is a reddish-brown gas and is partially responsible for the "brown haze" observed near large cities. In Alberta, transportation (automobiles, locomotives and aircraft) is the major source of NO<sub>x</sub>. Other major sources include the oil and gas industries and power plants.

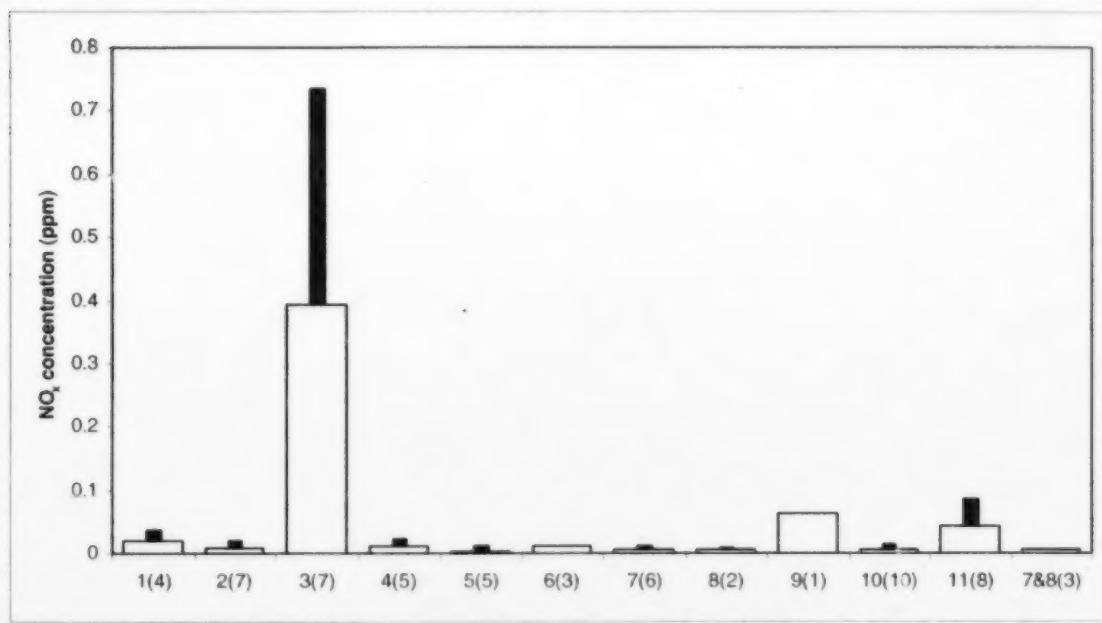
The highest NO<sub>x</sub> concentrations were measured at **Site 3** (Solex and Taylor Harmattan); recall that the highest CO concentrations were also measured at this location. The median and maximum one-hour average concentration of 0.394 and 0.736 ppm respectively were notably higher than concentrations measured at all other sites (Figure 10). Figures 10-12, illustrate that a significant fraction of the NO<sub>x</sub> consists of NO. Median one-hour average NO and NO<sub>2</sub> at **Site 3** were 0.393 and 0.031 ppm, respectively<sup>1</sup>. Typically, NO would readily be converted to NO<sub>2</sub> through reaction with O<sub>3</sub>; elevated NO concentrations at this location imply relatively fresh emissions. The MAML operator had noted the presence of continuous truck traffic at the site (Table A3); thus, truck emissions in the vicinity of the MAML was the most probable source of elevated NO<sub>x</sub> at Solex and Taylor Harmattan (**Site 3**). Somewhat elevated NO<sub>x</sub> concentrations were also observed at **Site 9** and **11**. Much like **Site 3**, elevated CO concentrations were also observed at these two sites. **Site 9** and **11** were located in Rocky Mountain House in proximity to major roadways, motor vehicle exhaust is the most likely source of the elevated NO<sub>x</sub> concentrations at these sites. Alberta has a one-hour AAAQO of 0.212 ppm for NO<sub>2</sub>. This objective was not exceeded at any of the monitoring locations. NO<sub>2</sub> was a minor contributor to elevated NO<sub>x</sub> concentrations measured during this study.

For the year 2006, median one-hour average NO<sub>x</sub> concentrations at Edmonton and Calgary Central were 0.029 and 0.031 ppm respectively. These values were lower than elevated measurements during this survey (notably **Site 3**), but were significantly higher than most median one-hour concentrations measured in this study. NO<sub>2</sub> concentrations for other MAML surveys are presented in Table A4. Median one-hour average concentration during other MAML

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<sup>1</sup> Quasi simulations method is used to measure NO, NO<sub>2</sub> and NO<sub>x</sub>, therefore, NO + NO<sub>2</sub> may not equal NO<sub>x</sub>.

surveys ranged from 0.001 to 0.014 ppm. The lower range concentration was measured for more than one survey; 0.014 ppm was measured for a survey conducted along the Edmonton Whitemud drive.



**Figure 10: Median and maximum one-hour average concentrations for NO<sub>x</sub>.**

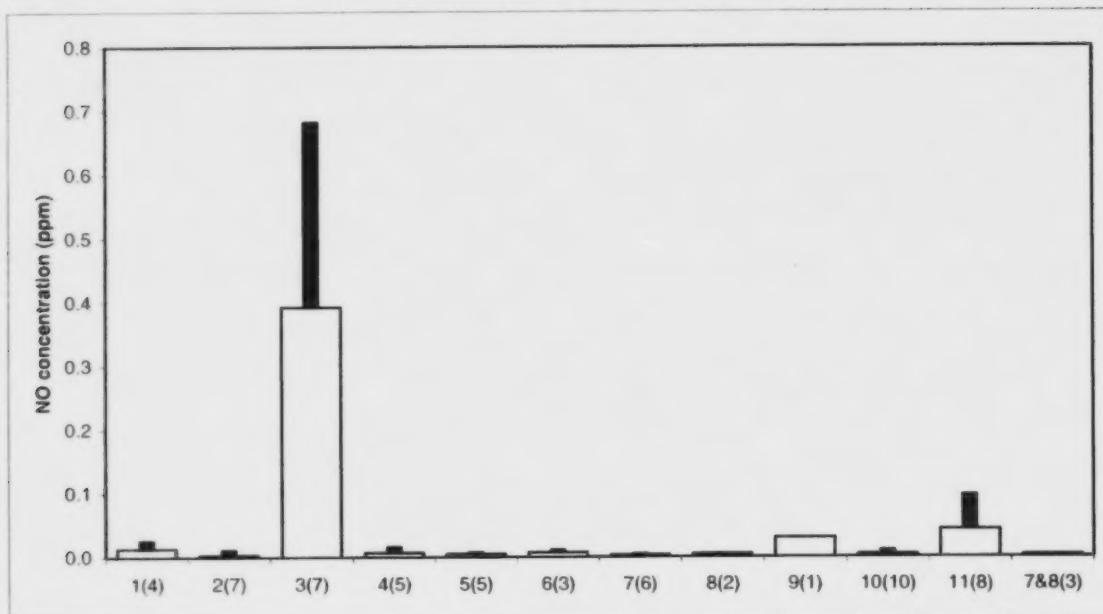


Figure 11: Median and maximum one-hour average concentrations for NO.

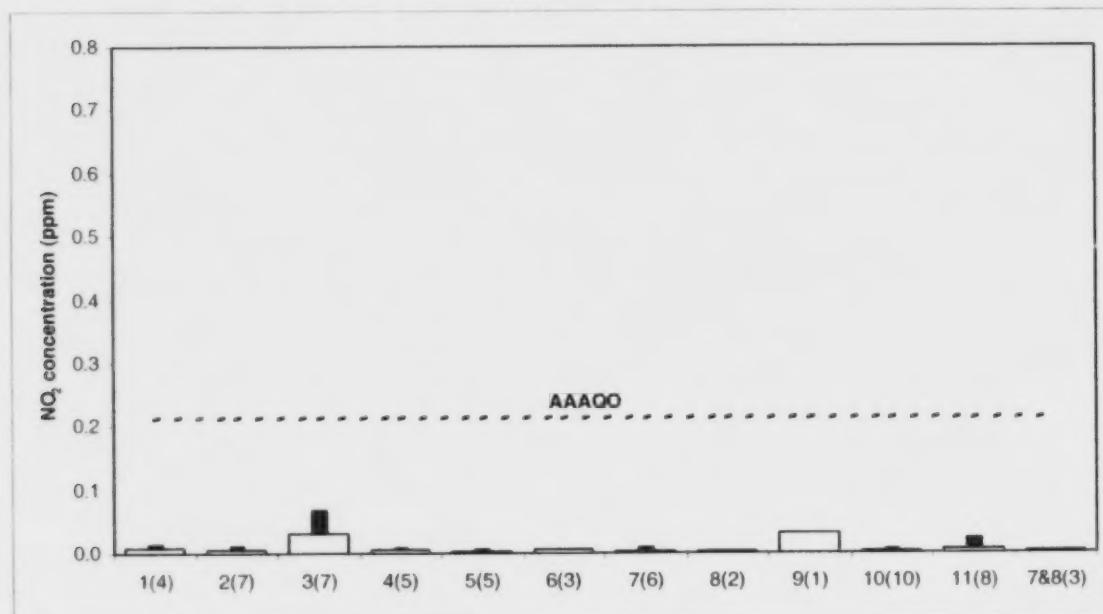


Figure 12: Median and maximum one-hour average concentrations for NO<sub>2</sub>. The y-axis has been set equivalent to Figures 8 and 9 to allow easy comparison.

## Ozone ( $O_3$ )

Ozone ( $O_3$ ) is not emitted directly by human activities. In the lower atmosphere it is formed through chemical reactions involving nitrogen dioxide ( $NO_2$ ) and volatile organic compounds (VOCs) in the presence of sunlight.  $O_3$  is a major component of smog.  $O_3$  concentrations are generally lower at urban locations. This is clearly evident in Table A3, where concentrations were lowest at the urban monitoring stations and highest at the rural stations. This is due to the destruction of  $O_3$  by vehicle-emitted nitric oxide (NO). Ozone levels are typically higher during the spring and summer months when solar radiation is readily available; this allows  $O_3$  forming chemical reactions to occur more rapidly.

One-hour average  $O_3$  concentrations for the current study range from 0.001 to 0.060 ppm. The one-hour AAAQO of 0.082 ppm was not exceeded at any of the monitoring locations. At most locations, the one-hour average  $O_3$  concentrations were comparable (Figure 13). The exceptions were **Site 3, 9 and 11**, where concentrations were lower. A lower  $O_3$  at these three sites is most probably due to the presence of significant NO (Figure 11). As already mentioned  $O_3$  is destroyed through reaction with NO. Furthermore, measurements at **Site 9** were only conducted during the winter months.

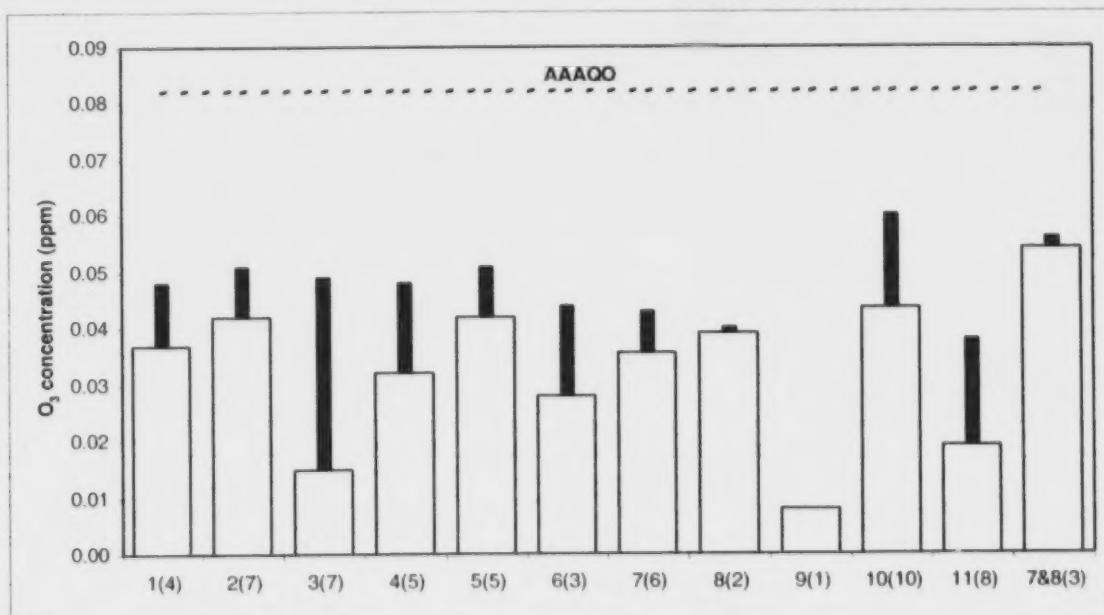


Figure 13: Median and maximum one-hour average ozone concentrations.

## **Polycyclic Aromatic Hydrocarbons (PAHs)**

Polycyclic aromatic hydrocarbons are organic compound consisting of two or more benzene rings and are formed through incomplete combustion. Ambient sources of PAHs include vehicle exhaust, wood smoke from residential and industrial use and forest fires. PAHs occur as complex mixtures and can be found as a gas or condensed onto particles. The phase of PAHs is dependant on ambient conditions such as temperature and the molecular structure of the compound. Larger PAHs (containing more benzene rings) tend to be found in the condensed phase (bound onto particles). It is these types of PAHs that are measured by the MAML. There are more than 100 different PAHs with varying levels of toxicity. PAHs usually occur as complex mixtures rather than single compounds.

PAHs are not monitored at permanent air quality stations. During other MAML surveys the median one-hour PAHs concentrations range from below detection limit to 11 ng/m<sup>3</sup> (Banff). In rural areas, the background PAHs concentrations in Alberta are typically below the detection limit of the instrument on board the MAML. Relatively high PAHs concentrations were measured at **Site 11** (Spongberg Enterprise). One-hour average concentrations at this location ranged from 3 to 43 ng/m<sup>2</sup>, with a median of 25 ng/m<sup>2</sup>. **Site 9** (Rocky Mountain House Industrial area) also had similarly high PAHs concentrations with one-hour average of 22 ng/m<sup>2</sup>. Monitoring at **Site 9** was performed for one hour only. As is illustrated in Figure 14, the median one-hour average PAHs concentrations at all *other* monitoring locations were lower than 6 g/m<sup>2</sup>.

**Sites 11** and **9** were located in Rocky Mountain House and in close proximity to Highway 22/11. Motor vehicle exhaust probably contributed to the elevated PAHs concentrations at these locations. Recall that CO and NO<sub>x</sub> concentrations were also elevated at these locations (Figures 9 and 10). Motor vehicle emission was also thought to have influenced **Site 3** (see section on CO and NO<sub>x</sub>). However, PAHs concentrations were not significantly elevated at this location, with a median one-hour concentration of 2 ng/m<sup>3</sup>. The type of vehicles, fuel and driving conditions may have influenced observations at these sites. For example, light duty vehicles have been found to be a significant source of heavier PAHs<sup>2</sup>; these PAHs are predominantly found in the particle phase and thus measured by the MAML. Light duty vehicles would have been most abundant on Highway 22/11 near **Site 11** and **9**. Heavy-

<sup>2</sup> Marr, L. C. et al., (1999). Characterization of polycyclic aromatic hydrocarbons in motor vehicle fuels and exhaust emissions. *Environmental Science and Technology*, 33, pp 3091-3099.

duty vehicles (such as the trucks at the terminal near **Site 3**) were a source of lighter PAHs<sup>3</sup>, typically found in the gas phase and thus not measured by the MAML.

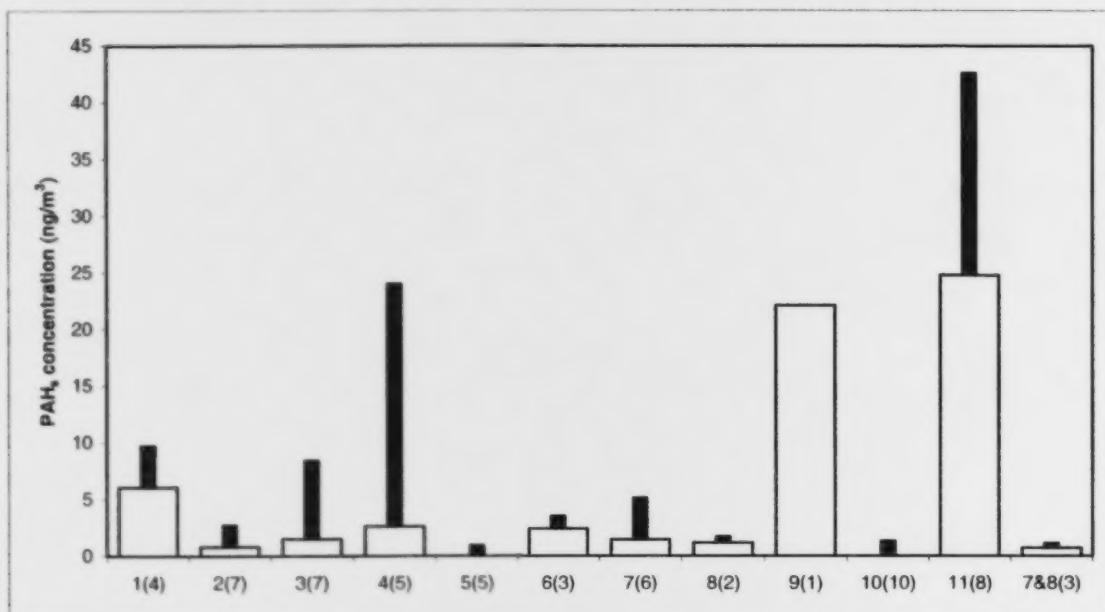


Figure 14: Median and maximum one-hour average concentrations for PAHs.

<sup>3</sup> Marr, L. C. et al., (1999). Characterization of polycyclic aromatic hydrocarbons in motor vehicle fuels and exhaust emissions. *Environmental Science and Technology*, **33**, pp 3091-3099.

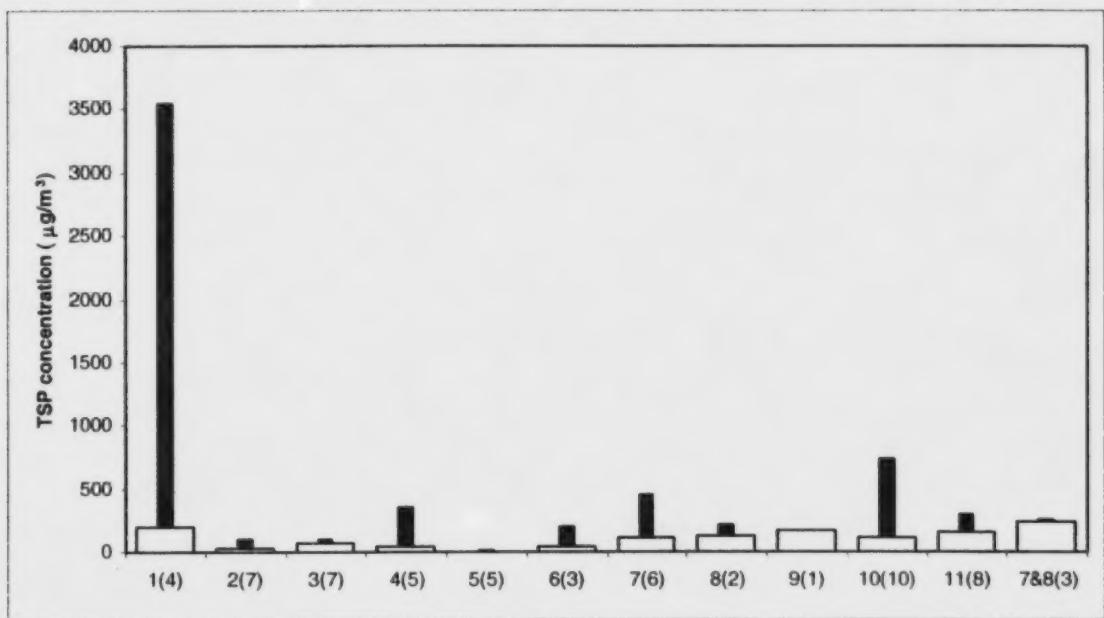
### **Particulate Matter (TSP, PM<sub>10</sub> and PM<sub>2.5</sub>)**

Inhalable particulates are particulate matter less than 10 micrometres in diameter (PM<sub>10</sub>) that can be inhaled into the nose and throat. Sources of PM<sub>10</sub> include soil dust, road dust, agricultural dust (e.g., harvest), smoke from forest fires and wood burning, vehicle exhaust and industrial emissions. Respirable particulates are particulate matter less than 2.5 micrometres (PM<sub>2.5</sub>) in diameter. PM<sub>2.5</sub> are small enough to penetrate into the lungs. Respirable particulates may form in the atmosphere and/or arise from combustion sources such as vehicle exhaust emissions, industrial emissions and wood burning. Total suspended particles (TSP) range in size from 0.001 to 500 micrometer; this group includes both PM<sub>10</sub> and PM<sub>2.5</sub>.

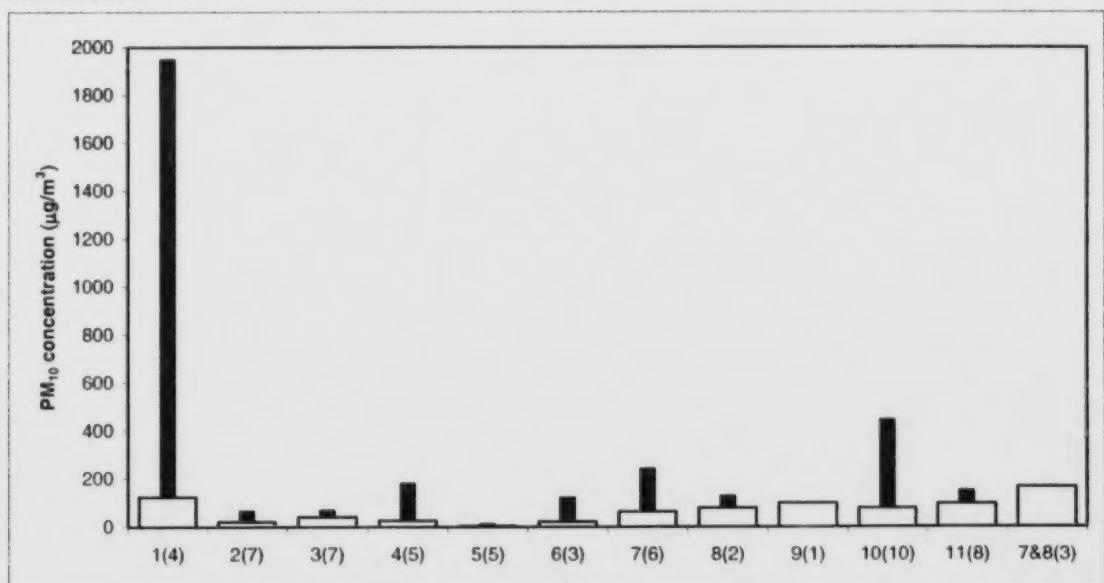
With the exception of the significantly elevated TSP concentration at **Site 1** (3553  $\mu\text{g}/\text{m}^3$ ), all other one-hour averages TSP were below 800  $\mu\text{g}/\text{m}^3$  (Figure 15). Elevated particulate concentrations at **Site 1** were due to dust re-suspended by passing trucks. The median one-hour TSP concentrations for the current study ranged from 6  $\mu\text{g}/\text{m}^3$  (**Site 5**, Petrofund) to 240  $\mu\text{g}/\text{m}^3$  (**Site 7&8**, West Fraser LVL Mill and Keyera Strachan). TSP and PM<sub>10</sub> are typically not monitored at permanent monitoring stations. The median TSP one-hour concentrations during other MAML surveys ranged from 7 to 149  $\mu\text{g}/\text{m}^3$ . The median concentrations measured for the current study, with the exception of **Site 7&8**, were within the range measured during other MAML surveys.

Median one-hour PM<sub>10</sub> concentration ranged from 3  $\mu\text{g}/\text{m}^3$  (**Site 5**, Petrofund) to 164  $\mu\text{g}/\text{m}^3$  (**Site 7&8**, West Fraser LVL Mill and Keyera Strachan). The median one-hour PM<sub>2.5</sub> concentrations ranged from below detection limit to 19  $\mu\text{g}/\text{m}^3$ . The highest median was measured downwind of both West Fraser LVL Mill and Keyera Strachan (**Site 7&8**). Higher concentration at **Site 7&8** may be due to the joint emissions from West Fraser LVL Mill and Keyera Strachan. When monitored individually concentrations were notably lower (Figures 15-17).

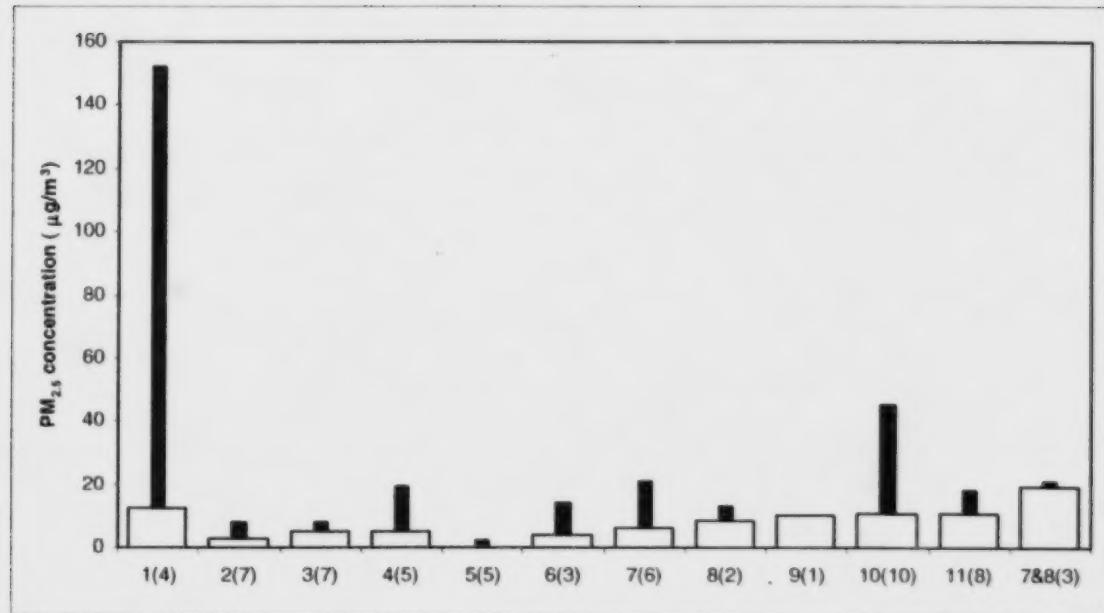
The median one-hour PM<sub>2.5</sub> concentrations at Edmonton and Calgary central stations for 2006 were 4 and 5  $\mu\text{g}/\text{m}^3$  (Table A3). At Beverlodge (permanent rural monitoring station) this concentration was lower at 3  $\mu\text{g}/\text{m}^3$ . Median one-hour average PM<sub>2.5</sub> concentrations at a number of the monitoring sites were higher than measured at the above-mentioned permanent monitoring stations.



**Figure 15: Median and maximum one-hour average total suspended particle concentrations**



**Figure 16: Median and maximum one-hour average PM<sub>10</sub> concentrations**



**Figure 17: Median and maximum one-hour average PM<sub>2.5</sub> concentrations**

## ***Appendix A***

Table A1: Median one-hour average concentrations at monitoring locations in the Caroline and Rocky Mountain House area.

Monitoring Site	Facility	CO PPM	O <sub>3</sub> PPM	THC PPM	CH <sub>4</sub> PPM	RHC PPM	SO <sub>2</sub> PPM	NO PPM	NO <sub>2</sub> PPM	NO <sub>x</sub> PPM	NH <sub>3</sub> PPM	TRS PPM	H <sub>2</sub> S PPM	TSP µg/m <sup>3</sup>	PM <sub>10</sub> µg/m <sup>3</sup>	PM <sub>2.5</sub> µg/m <sup>3</sup>	PAHs ng/m <sup>3</sup>
1	New Alta Stauffer	0.2	0.037	3.8	1.9	1.9	0.002	0.014	0.009	0.020	0.007	0.001	bd	199	124	13	6
2	Shell Caroline	0.2	0.042	1.7	1.8	bd	0.003	0.003	0.006	0.008	0.003	0.001	bd	34	21	3	1
3	Harmattan Solex	1.3	0.015	2.2	2.1	0.1	0.006	0.393	0.031	0.394	0.024	0.003	0.005	68	42	5	2
4	Devon Ferrier Acres	0.4	0.032	1.8	1.9	bd	0.001	0.007	0.006	0.011	0.005	0.001	bd	37	26	5	3
5	Petrofund Ferrier	0.3	0.042	3.2	2.1	1.3	0.001	0.005	0.002	0.004	0.001	0.001	bd	6	3	bd	bd
6	Devon (nee Numac) Ferrier Cardium #2	0.1	0.028	2.7	2.1	0.7	0.001	0.007	0.005	0.010	0.004	bd	bd	38	21	4	2
7	West Fraser Mill	0.1	0.036	1.7	1.7	bd	0.002	0.003	0.002	0.005	0.002	0.001	bd	113	84	8	1
7&8	West Fraser and Keyara Strachan	0.1	0.039	1.7	1.7	bd	0.004	0.005	0.003	0.007	0.005	0.002	bd	132	79	9	1
8	Keyera Strachan Gas Plant	0.7	0.008	2.4	1.9	0.6	0.003	0.030	0.032	0.062	0.002	0.001	bd	173	99	10	22
9	Terroco east Rocky Mtn Hse.	0.1	0.044	1.7	1.7	bd	0.011	0.004	0.003	0.006	0.002	0.003	0.002	113	78	11	bd
10	Husky Ram River	0.4	0.019	1.9	2.0	bd	0.001	0.043	0.007	0.042	0.011	0.001	0.001	157	96	11	25
11	Spongberg at Rocky Mtn House	0.2	0.054	1.6	1.7	bd	0.004	0.003	0.004	0.005	bd	0.001	0.001	240	164	19	1

Table A2: Maximum one-hour average concentrations at monitoring locations in the Caroline and Rocky Mountain House area.

Monitoring Site	Facility	CO PPM	O <sub>3</sub> PPM	THC PPM	CH <sub>4</sub> PPM	RHC PPM	SO <sub>2</sub> PPM	NO PPM	NO <sub>2</sub> PPM	NO <sub>x</sub> PPM	NH <sub>3</sub> PPM	TRS PPM	H <sub>2</sub> S PPM	TSP µg/m <sup>3</sup>	PM <sub>10</sub> µg/m <sup>3</sup>	PM <sub>2.5</sub> µg/m <sup>3</sup>	PAHs ng/m <sup>3</sup>
1	New Alta Stauffer	0.4	0.048	8.8	1.9	6.5	0.004	0.026	0.014	0.036	0.015	0.001	0.001	3553	1947	152	10
2	Shell Caroline	0.3	0.051	1.8	1.8	bd	0.005	0.011	0.010	0.020	0.006	0.003	0.002	95	64	8	3
3	Harmattan Solex	2.6	0.049	6.8	2.7	4.0	0.008	0.682	0.068	0.736	0.273	0.006	0.009	99	68	8	8
4	Devon Ferrier Acres	0.6	0.048	2.2	2.0	0.2	0.001	0.016	0.009	0.024	0.009	0.001	0.001	347	179	19	24
5	Petrofund Ferrier	0.4	0.051	8.5	3.4	5.4	0.001	0.007	0.005	0.011	0.001	0.001	0.001	16	11	2	1
6	Devon (nee Numac) Ferrier Cardium #2	0.2	0.044	3.5	2.2	1.1	0.001	0.011	0.006	0.011	0.011	0.007	0.008	193	120	14	4
7	West Fraser Mill	0.1	0.043	1.9	1.9	bd	0.009	0.005	0.008	0.011	0.018	0.002	0.001	450	240	21	5
7&8	West Fraser and Keyara Strachan	0.2	0.040	1.7	1.7	bd	0.004	0.005	0.003	0.008	0.005	0.002	bd	212	126	13	2
8	Keyera Strachan Gas Plant	0.7	0.008	2.4	1.9	0.6	0.003	0.030	0.032	0.062	0.002	0.001	bd	173	99	10	22
9	Terroco east Rocky Mtn Hse.	0.5	0.060	2.4	2.3	0.2	0.063	0.010	0.006	0.013	0.005	0.015	0.006	728	444	45	1
10	Husky Ram River,	1.2	0.038	3.5	3.3	0.3	0.002	0.097	0.023	0.066	0.019	0.002	0.005	299	148	18	43
11	Spongberg at Rocky Mtn House	0.2	0.056	1.6	1.7	bd	0.004	0.003	0.004	0.005	0.002	0.001	0.001	259	165	21	1

**Notes:**

bd – below detection limit

ppm - parts per million ng/m<sup>3</sup> = nanograms per cubic meter µg/m<sup>3</sup> = micrograms per cubic meter n/a – Parameter not monitored or data not available.

Table 3A: Median one-hour average concentrations measured at selected MAML surveys and permanent monitoring stations.

Station or Survey Type	Air Quality Station or Survey Name	Monitoring Period	CO ppm	O <sub>3</sub> ppm	THC ppm	CH <sub>4</sub> ppm	RHC ppm	SO <sub>2</sub> ppm	NO <sub>2</sub> ppm	NH <sub>3</sub> ppm	TRS ppm	H <sub>2</sub> S ppm	TSP µg/m <sup>3</sup>	PM <sub>10</sub> µg/m <sup>3</sup>	PM <sub>2.5</sub> µg/m <sup>3</sup>	PAH ng/m <sup>3</sup>
mobile	Caroline <sup>1</sup> (current survey)	Oct 05 & Jan, May, Jun 06	0.2	0.038	1.8	1.8	bd	0.002	0.004	0.003	0.001	0.001	79	49	6	1
	Girouxville (spring 2006) <sup>1</sup>	April 27-28, 2006	0.3	0.045	2.1	2.1	bd	0.001	0.002	0.095	0.002	0.001	149	82	8	1
	Girouxville (spring 2005) <sup>1</sup>	June 14 and 15, 2005	0.4	0.027	1.9	1.9	bd	0.002	0.001	0.012	0.001	0.001	21	15	2	bd
	Girouxville (fall 2004) <sup>1</sup>	29 Nov - 1 Dec, 2004	0.2	0.027	2.2	2.1	bd	0.001	0.001	0.009	0.001	bd	14	8	1	bd
	Whitecourt <sup>2</sup>	Sep 6 - 7, 2005	0.2	0.027	2.1	2.1	bd	0.001	0.002	0.084	0.001	0.001	28	16	2	1
	Lloydminster <sup>1</sup>	Jan. 2002 to Nov. 2004	0.2	0.030	2.5	2.2	0.2	0.001	0.006	0.001	0.001	bd	19	13	2	3
	Lakeland Area <sup>1</sup>	May 2003 to Sep. 2004	0.2	0.031	2.6	2.4	0.2	bd	0.002	0.002	bd	bd	14	9	1	bd
	Banff <sup>1</sup>	Nov. 19 - 23, 2003	0.5	0.018	2.7	2.5	0.2	bd	0.008	0.004	bd	0.001	7	5	1	11
	Fort Saskatchewan/Redwater <sup>1</sup>	May 2001 to Mar. 2002	0.3	0.029	2.1	2.1	0.1	0.001	0.004	0.001	bd	bd	39	22	3	bd
	Cold Lake/Bonnyville/Elk Point <sup>1</sup>	Mar. 2001 to Feb. 2002	0.2	0.031	2.1	1.9	0.1	bd	0.003	0.000	0.001	bd	16	10	2	1
	Whitecourt/Swan Hills/Shiningbank Lake <sup>1</sup>	Mar. 2001 to Jun. 2001	0.2	0.027	2.3	2.0	0.3	0.004	0.005	0.001	0.001	bd	47	29	4	1
	Wabamun <sup>1</sup>	Jul. 2000 to Sep. 2001	0.2	0.027	2.0	1.9	0.1	0.002	0.005	0.004	bd	bd	34	22	3	1
	Edmonton Whitemud Drive	Jun 2000 to Jul 2001	0.4	0.019	2.2	2.0	0.1	0.002	0.014	bd	bd	bd	41	24	3	8
Permanent Continuous Monitoring Stations																
Urban	Calgary Central <sup>2</sup>	Jan-Dec 2006	0.4	0.015	2.0	n/a	n/a	n/a	0.022	n/a	n/a	n/a	n/a	20	5	n/a
	Edmonton Central <sup>2</sup>	Jan-Dec 2006	0.3	0.016	2.1	n/a	n/a	n/a	0.019	n/a	n/a	n/a	n/a	n/a	4	n/a
small Urban	Fort McMurray <sup>3</sup>	Jan-Dec 2006	n/a	0.021	2.0	n/a	n/a	bd	0.003	n/a	bd	n/a	n/a	n/a	3	n/a
	Red Deer <sup>2</sup>	Jan-Dec 2006	0.3	0.025	2.0	2.0	n/a	bd	0.008	n/a	n/a	bd	n/a	n/a	4	n/a
Industrial	Buffalo viewpoint <sup>3</sup>	Jan-Dec 2006	n/a	n/a	2.0	n/a	n/a	bd	n/a	n/a	n/a	bd	n/a	n/a	n/a	n/a
	Mannix <sup>3</sup>	Jan-Dec 2006	n/a	n/a	2.0	n/a	n/a	0.001	n/a	n/a	n/a	bd	n/a	n/a	n/a	n/a
	Mildred Lake <sup>3</sup>	Jan-Dec 2006	n/a	n/a	2.0	n/a	n/a	bd	n/a	n/a	n/a	bd	n/a	n/a	n/a	n/a
Rural	Beaverlodge <sup>2</sup>	Jan-Dec 2006	n/a	0.030	n/a	n/a	n/a	bd	0.002	n/a	n/a	n/a	n/a	n/a	3	n/a
	Caroline <sup>5</sup>	Jan-Dec 2006	n/a	0.035	2.1	n/a	n/a	bd	0.002	n/a	bd	n/a	n/a	n/a	n/a	n/a

Notes:

bd - below detection limit

ppm - parts per million ng/m<sup>3</sup> = nanograms per cubic meter µg/m<sup>3</sup> = micrograms per cubic meter n/a - Parameter not monitored or data not available.

1 - Mobile survey conducted by Alberta Environment.

2 - Station operated by Alberta Environment.

3 - Station operated by the Wood Buffalo Environmental Association.

4 - Station operated by the West Central Airshed Society.

5 - Station operated by the Strathcona Industrial Association.

6 - Station operated by the Parkland Airshed Management Association.

**Table A4: Operator's comment and meteorological conditions measured at monitoring locations**

Date	Start/End Times	Site	Facility	Comments	Temp DegC	RH %RH	WSP KPH	WDR DEG
12-Oct-05	10:33 to 11:34	1	New Alta Stauffer	Outside main gate on TR 372. Odours and dust from trucks	16.9	29.0	5.4	SSW
12-Oct-05	12:04 to 13:07	2	Shell Caroline	Overflow parking area odours evident	15.1	30.0	17.7	WSW
12-Oct-05	13:49 to 14:49	3	Harmattan Solex	H <sub>2</sub> S - possible interference from NO <sub>x</sub> compressors	16.4	29.4	18.4	W
12-Oct-05	14:49 to 15:49	3	Harmattan Solex		15.0	31.9	13.8	W
12-Oct-05	16:35 to 17:36	2	Shell Caroline	Occasional slight odours from plant	13.0	36.4	10.4	SW
13-Oct-05	07:57 to 08:39	11	Spongberg Ent at Rocky Mtn House	Very light wind speed - no odours	7.5	64.7	3.5	WSW
13-Oct-05	09:12 to 10:14	4	Devon Ferrier (Ferrier Acres)	- 200m downwind of plant no odours	11.2	51.6	8.7	SSW
13-Oct-05	13:56 to 14:56	5	Petrofund Ferrier	Odours are intermittent, evident whenever wind dir. places MAML downwind	10.0	69.5	4.6	W
13-Oct-05	14:56 to 15:56	5	Petrofund Ferrier	Very light wind speed and variable wind direction	10.1	60.8	4.5	W
13-Oct-05	16:40 to 17:13	11	Spongberg Ent at Rocky Mtn House	Downwind of Spongberg no odours - CO likely from hwy 11 traffic	12.1	50.1	4.0	SW
14-Oct-05	07:27 to 08:29	11	Spongberg Ent at Rocky Mtn House	Elevated CO and NO <sub>x</sub> levels likely due to Highway traffic	-0.3	88.7	2.4	SSW
14-Oct-05	08:41 to 09:41	6	Devon Ferrier Cardium #2	Occasional odours	3.2	74.8	2.4	SSE
14-Oct-05	10:26 to 11:26	7	West Fraser Mill	1km from mill smell of sawdust evident. Dust from trucks SO <sub>2</sub> from Keyera	9.0	41.9	7.5	ESE
14-Oct-05	11:38 to 12:39	7	West Fraser Mill	1km from mill smell of sawdust evident. Dust from trucks SO <sub>2</sub> from Keyera	9.1	45.6	9.2	ESE
14-Oct-05	13:09 to 14:09	10	Husky Ram River	1km north on Wellsite road, very slight sulphur odour	9.3	42.3	4.8	ESE
14-Oct-05	14:09 to 14:48	10	Husky Ram River	Very slight sulphur odour	9.9	37.4	5.2	SSE
24-Jan-06	11:42 to 12:43	1	New Alta Stauffer	Corner of Hwy 761 & TR 372 - Odours and continuous truck traffic	11.0	37.8	3.6	SSW
24-Jan-06	13:15 to 14:23	2	Shell Caroline	On plant access Rd slight fleeting odours	12.2	31.2	9.2	ESE
24-Jan-06	15:07 to 16:07	3	Harmattan Solex	On RR 42 strong odours and continuous truck traffic at terminal	12.6	30.8	17.1	SSW
24-Jan-06	16:07 to 17:07	3	Harmattan Solex	On RR 42 strong odours and continuous truck traffic at terminal	12.3	30.1	13.2	SSW
24-Jan-06	17:53 to 18:54	2	Shell Caroline	On plant access Rd occasional odours evident	10.9	27.7	16.6	SW
25-Jan-06	08:04 to 09:05	11	Spongberg Ent at Rocky Mtn House	Downwind of facility but no odours	3.7	47.3	5.0	SSW
25-Jan-06	10:05 to 11:05	6	Devon Ferrier Cardium #2	Some hydrocarbon odours	4.4	48.7	3.6	SSW
25-Jan-06	11:17 to 12:17	4	Devon Ferrier Acres	Near plant gate - very light wind and only very slight odours	11.9	25.9	2.4	SW
25-Jan-06	13:02 to 14:08	8	Keyera Strachan Gas Plant	Dust from trucks passing nearby	14.5	18.8	5.0	SW
25-Jan-06	14:24 to 15:24	7	West Fraser Mill	Dust from mill operations	14.0	20.7	7.1	SSW
25-Jan-06	15:25 to 16:24	7	West Fraser Mill	Move around the corner to a different spot from previous measurement	12.6	23.8	7.7	SSW
25-Jan-06	17:07 to 18:07	10	Husky Ram River	Stop at new wellsite clearing, ~1km NE of plant	7.6	32.5	4.5	SSE
25-Jan-06	18:08 to 19:07	10	Husky Ram River	H <sub>2</sub> S and sulphur odours for entire monitoring period	7.2	33.7	7.8	S
26-Jan-06	08:38 to 09:37	9	Terroc east Rocky Mtn Hse	Faint hydrocarbon smell	0.8	62.8	4.0	W
26-Jan-06	09:53 to 10:53	4	Devon Ferrier Acres	Very faint odours	2.8	58.6	1.9	SSW
26-Jan-06	13:11 to 14:12	5	Petrofund Ferrier	Occasional fleeting odours as wind direction changes	6.4	24.3	12.1	WSW

Continued ...

Table A4: Operator's comment and meteorological conditions measured at monitoring locations (continued)

Date	Start/End Times	Site	Facility	Comments	Temp DegC	RH %RH	WSP KPH	WDR DEG
10-May-06	10:45 to 11:47	1	New Alta Stauffer	Clear sky- very slight occasional odours	16.1	24.1	5.7	SSE
10-May-06	12:21 to 13:21	2	Shell Caroline	Stopped on the west side of gas plant occasional strong odours	16.1	24.2	15.0	SE
10-May-06	14:22 to 15:22	3	Taylor Harmattan	Some gas plant odour	17.9	20.4	14.5	ESE
10-May-06	15:22 to 16:22	3	Taylor Harmattan	Some gas plant odour	17.3	20.1	17.9	ESE
10-May-06	17:08 to 18:08	2	Shell Caroline	Stop on west side of plant, 500m from stack, some odours	17.6	22.2	16.5	ESE
11-May-06	07:34 to 08:36	11	Spongberg Ent at Rocky Mtn House	No odours	12.2	36.0	3.9	SSW
11-May-06	08:47 to 09:47	8	Devon (nee Numac) Ferrier Cardium #2	No odours, dust from trucks	18.2	26.6	5.6	SSE
11-May-06	10:41 to 11:41	7&8	West Fraser and Keyera Strachan	Odours and dust from West Fraser	17.3	24.7	10.1	SE
11-May-06	11:41 to 12:41	7&8	West Fraser and Keyera Strachan	SO <sub>2</sub> from Keyera	17.7	23.9	13.3	SE
11-May-06	12:41 to 13:41	7&8	West Fraser and Keyera Strachan	Both facilities upwind	17.3	24.2	18.9	SE
11-May-06	14:28 to 15:28	10	Husky Ram River	Occasional strong odours from plant	19.5	22.1	7.4	SE
11-May-06	15:28 to 16:28	10	Husky Ram River	Occasional strong odours from plant	16.5	27.6	7.3	SE
12-May-06	07:52 to 08:54	11	Spongberg Ent at Rocky Mtn House	Occasional very slight odours	14.5	48.2	9.1	SW
12-May-06	09:11 to 10:20	4	Devon Ferrier Acres	Downwind of facility but no odours	17.0	33.5	6.6	SW
12-May-06	11:00 to 12:00	5	Petrofund Ferrier	Occasional strong odours	14.3	49.8	6.6	ENE
12-May-06	12:00 to 13:00	5	Petrofund Ferrier	Occasional strong odours	17.1	37.7	9.3	E
26-Jun-06	10:44 to 11:52	1	New Alta Stauffer	Some oil odours	26.3	43.7	10.7	ESE
26-Jun-06	15:34 to 16:38	3	Taylor Harmattan	1 mile from plant on Hwy 22	27.8	40.1	15.3	S
26-Jun-06	17:20 to 18:21	2	Shell Caroline	Wellsite Rd. just NW of plant lots of activity	26.7	38.5	19.2	SSE
27-Jun-06	07:30 to 08:27	11	Spongberg Ent at Rocky Mtn House	no odours, particulates from road dust	25.1	54.3	3.0	SSW
27-Jun-06	09:34 to 10:38	8	Keyera Strachan Gas Plant	faint occasional odours, at fence line	31.6	24.9	5.5	SSE
27-Jun-06	11:38 to 12:38	7	West Fraser Mill	In woodlot to the SW of mill approx 800m	29.1	29.6	13.3	E
27-Jun-06	12:38 to 13:38	7	West Fraser Mill		28.6	34.2	12.6	E
27-Jun-06	14:20 to 15:21	10	Husky Ram River	Wellsite road on North side of plant DW of main stack	30.8	29.1	8.5	ESE
27-Jun-06	15:24 to 16:29	10	Husky Ram River	Particulates from road dust	30.5	32.4	8.6	SE
27-Jun-06	16:35 to 17:38	10	Husky Ram River	Particulates from road dust	29.5	33.4	8.1	SE
28-Jun-06	07:33 to 08:36	11	Spongberg Ent at Rocky Mtn House	Parked on Hwy 11 to the SE	22.3	51.3	8.7	SE
28-Jun-06	08:58 to 10:00	4	Devon Ferrier Acres	Very slight fleeting odours	25.0	41.6	9.1	W
28-Jun-06	12:25 to 13:30	10	Husky Ram River	Odours evident at intersection near plant gate	26.6	38.7	12.3	E

Notes:

Temp - Temperature in degrees centigrade RH - Relative humidity in percentage WSP KPH - Wind speed in Km/hr WDR DEG - Wind direction in degrees

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